

SUBJECT: Performance of the Apollo
Launch Vehicle (CCS-OMNI)/
MSFN Communication Link
Case 320

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FROM: N. W. Schroeder

MEMORANDUM FOR FILE

Communications margins for the Apollo Launch Vehicle Command and Communication System/Manned Space Flight Network (CCS/MSFN) link have been calculated for the case in which only the low gain "Omni" antenna is used on the vehicle. The purpose of these calculations is to determine the expected performance of this link for the period in the Apollo lunar mission following the SIVB separation. The results of these calculations are tabulated in Table I and the system parameters that were used in these calculations are tabulated in Table II.

The results that have been obtained are summarized as follows:

1. The up-data power margins, at a range of 25,000 nautical miles, are positive for both the MSFN (85' diameter antennas) and MSFN (30' diameter antennas) stations.
2. The 72kbps telemetry (TLM) and ranging margins, at a range of 25,000 nautical miles, are positive for the MSFN (85') stations, but the telemetry margin at this range is negative for the MSFN (30') stations.
3. Based on the current system parameters, the maximum ranges for which positive margins can be expected for the 72kbps telemetry data, when telemetry and ranging are transmitted simultaneously, are the following:

<u>MSFN Antenna</u>	<u>Maximum Range</u>
MSFN(85')	35,388 N.Mi.
MSFN(30')	16,739

In all of the results presented, it was assumed that the MSFN would transmit at a 10 kilowatt power level and that the vehicle antenna gain (transmit and receive) would equal -3dB which is the measured gain over 68% of the sphere.

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4. Based on the current system parameters, the maximum ranges for which the range code acquisition time is a maximum of 60 seconds - provided that only ranging is transmitted on the up link and down link, are 114,983 and 85,840 nautical miles respectively for the MSFN (30' diameter antenna) stations equipped with cooled and uncooled paramps respectively.

Conclusions

For a range of 25,000 nautical miles, positive 72 kbps TLM margins can be expected for the CCS(Omni)/MSFN communications link for those stations equipped with 85' antennas, but negative margins (resulting in a BER of approximately 10^{-3}) can be expected for those stations equipped with 30' antennas.

Although the use of the 30' (uncooled paramp) station is limited to a vehicle range of about 11,400 nautical miles for the reception of 72 kbps TLM data, this station could be used effectively for ranging up to about 85,500 nautical miles.

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TABLE I
Performance of the CCS(Omni)/MSFN(85', 30')

Communications Links
(Worst Case)

Service-Services Transmitted	(PMIN)* Minimum Received Power (for Circuit Margin ≥ 0)	(M _p) Power Margin (for R= 25,000 N.Mi.)	R _{MAX} Maximum Range (for M _p ≥ 0)
<u>I. Using an MSFN (85') Station</u>			
Up Data - Up Data & Ranging	-133.5 dBW (-133.0)	25.1 dB	418,466.N.M:
72k BPS TLM - TLM & Ranging	-139.7 (-139.7)	3.0	35,388.
Ranging - TLM & Ranging	-155.1 (-152.1)	18.4	147,930.
<u>II. Using an MSFN (30'-cooled) Station</u>			
Up Data - Up Data & Ranging	-133.5 dBW (-133.0)	18.1 dB	191,938. N.Mi.
- Up Data Only	-134.2	18.7	197,429.
72k BPS TLM - TLM & Ranging	-139.7 (-139.7)	-3.5	16,739.
- TLM Only	-140.6	-2.6	18,434.
Ranging - TLM & Ranging	-154.6 (-152.0)	11.4	69,256.
- Ranging Only	-161.8 (-156.5)	18.6	114,983.
<u>III. Using an MSFN (30'-uncooled) Station</u>			
Up Data - Up Data Only	-133.4 dBW		197,429. N. Mi.
72k BPS TLM - TLM Only	-136.4		11,423.
Ranging - Ranging Only	(-153.9)		85,840

*The parentheses indicate the minimum received power for the maximum range indicated. The magnitude of power not in parentheses refers to that required for a range of 25,000. nautical miles. The difference between these two powers is caused by the dependence of the turn around channel gain (which is zero for non-ranging modes) on the uplink signal strength.

TABLE II

System Parameters for the Command and Communications System (CCS) and the MSFN

<u>Parameter</u>	Nom.	Case	Worst Case	Units	Reference
Transponder					
Uplink Carrier Frequency (Fu)	2101.802	-----		MH _Z	2
Downlink Carrier Frequency (Fd)	2282.5	-----		MH _Z	2
NSD Constant (Au)	5800	-----		°K	1*
NSD Constant (Bu)	2.75×10^{13}	-----		°K/Watt	1*
Turn Around Constant (Ro)	.6	-----		---	3
IF Bandwidth B _{ts})	4.6×10^6	-----		H _Z	4
Video Bandwidth (BV)	1.7×10^6	-----		H _Z	1*
Carrier Detector Bandwidth (Buc)	800	-----		H _Z	3
Up Data Detection Bandwidth	20×10^3	-----		H _Z	2
Required "(S/N) _{ucr} " for Uplink Carrier	6	-----		dB	2
Required "(S/N) _{uw} " for Up Data	10	-----		dB	2
Transmitter Power	15	-----		Watts	3
Antenna Gain (68% of sphere)	-3	-----		dB	3
Circuit Losses	3.04	-----		dB	3
Modulation Index for 72k BPS TLM	1.22	-----		radians	3
MSFN					
Uplink Carrier Frequency (Fu)	2101.802	-----		MH _Z	2
Downlink Carrier Frequency (Fd)	2282.5	-----		MH _Z	2
NSD Constant (Ad) 30' Cooled-Quiet Sky)	96	-----		°K	1
NSD Constant (Ad) 30' Uncooled Quiet Sky)	250	-----		°K	1
NSD Constant (Ad) 85' Quiet Sky)	96	-----		°K	1
NSD Constant (Bd)	$.305 \times 10^{16}$	-----		Watts/°K	1
IF Bandwidth	4.8×10^6	5.3×10^6		H _Z	1
Carrier Loop Bandwidth	700	-----		H _Z	2

*These parameters were not available for the CCS; however, since they are considered to be similar to those of the CSM, CSM parameters were used as noted.

TABLE II (continued)

System Parameters for the Command and
Communications System (CCS) and the MSFN

Parameter	Nom. Case	Worst Case	Units	Reference
MSFN				
72 kbps TLM Predetection Bandwidth	300×10^3	-----	H _z	3
Required "(S/N) _{dc} for Downlink Carrier	12	-----	dB	1
Required "(S/N) _{dw} for 72k BPS TLM	10.*	-----	dB	2
Required "(S/N) _{cor} for Range Code	32**	-----	dB	2
Transmitter Power	10^4	9500	Watts	1
Antenna Gain -30' transmit	43	-----	dB	1
Antenna Gain -30' Receive	44	-----	dB	1
Antenna Gain 85' Transmit	52	50	dB	1
Antenna Gain 85' Receive	53	50.5	dB	1
Modulation Index for Up Data	1.22	-----	radians	3
Modulation Index for Range Code	.34	-----	radians	3

*The worst case subcarrier to noise power ratio calculated from the 13dB total received signal to noise power ratio used by Marshal for a BER of 10^{-6} .

**Signal level required for 60 sec. code acquisition time.

REFERENCES FOR TABLE II

1. NASA - MSC/ISD Master Parameter List dated March 12, 1968.
2. Apollo Launch Vehicle/MSFN Performance and Interface Specification, February 9, 1967.
3. Telephone Conversation with Mr. Joe Kerr, Marshall.
4. Final Report - Electronic Systems Test Program CCS Transponder/MSFN RER Compatibility and Performance Evaluation, B.R. Reed, C. J. Stoker Report EB66-3302-U, April 15, 1966 Information Systems Division; NASA Manned Spaceflight Center, Houston Texas.

TABLE III

Received Signal Powers for the
CCS(Omni)/MSFN Communications Link
for Range = 25,000. nautical miles

Transmitting Antenna	Receiving Antenna	Transmitted Power	Received Power
MSFN(85')	CCS(Omni)	9500. watts	-108.5 dBW
MSFN(30')	CCS(Omni)	9500.	-115.5
CCS(Omni)	MSFN(85')	15.	-136.7
CCS(Omni)	MSFN(30')	15.	-143.2

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